§13. Fatigue Crack Propagation Rate of SUS316 and Weld Joint at 7 K

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An austenitic steel of SUS316 was used for cryogenic support structures of the Large Helical Device. The maximum thickness is 100 mm and the structures were assembled by welding. It was required to keep the welding residual deformation within ± 2 mm, when the welding was carried out. So, the partial welding was performed from both surfaces to reduce a total heat input and an amount of the filler metal. As the results, a metal-touched region remained at the mid section of the thick plate. To prevent the crack-like flaws from generating, and to reduce the stress concentration of an electro-magnetic force, small grooves were designed at the weld root.

Since the LHD is not a pulse device like a Tokamak type, a fatigue failure would not be expected as a main fracture. However, the fatigue crack will become an origin to cause a structural problem. Therefore, the fatigue crack propagation tests were planed and carried out at 7 K.

A weld joint specimen in a compact tension type was machined out from the welded plate shown in Fig.1. It contained a natural crack at the weld root, and the fatigue crack initiated at the weld root and grew to TIG weld metal. The weld joint was not heat-treated before test. As a reference, a base metal specimen was also prepared and the fatigue crack was propagated to the thickness direction.

The fatigue crack tests were carried out at 7 K.

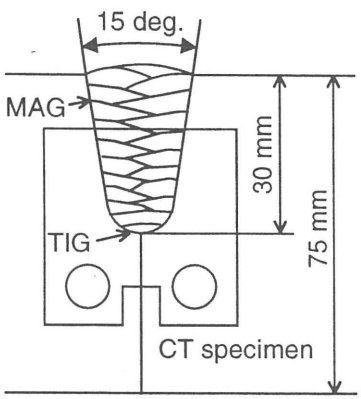

Fig.1. Location of test specimen in weld joint.

A stress ratio was 0.1, and a frequency was 40 Hz. The fatigue crack length was measured by a fiber scope, of which magnification was 7 times, at an interval of certain cycles (ΔN). The fatigue crack propagation rate (da/dN) was obtained by dividing a crack extension (Δa) by a number of cycles (ΔN) of the interval.

Figure 2 shows the test results together with the data of other cryogenic structural materials. The data for SUS316 base metal is plotted near the reported property line of 316 base metal by R.L. Tobler and R.P. Reed. The fatigue crack growth property of SUS316 for LHD is almost same as 316LN aged material. On the other hand, the weld joint specimen showed about 1/5 lower fatigue crack growth rate than a base metal. This lower rate is considered to be caused by the compressive welding residual stress around the weld root. The propagation rate in the weld metal is almost same as or rather smaller than that of Incoloy 908.

Since the compressive residual stress in LHD structures will be larger than in the specimen, the propagation rate is expected to be much lower.

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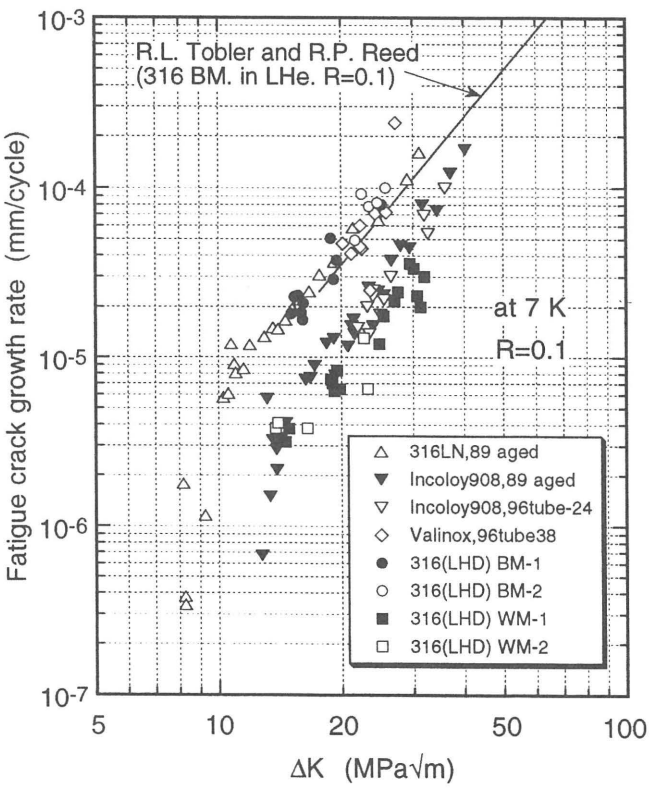

Fig.2. Relation between da/dN and ΔK.